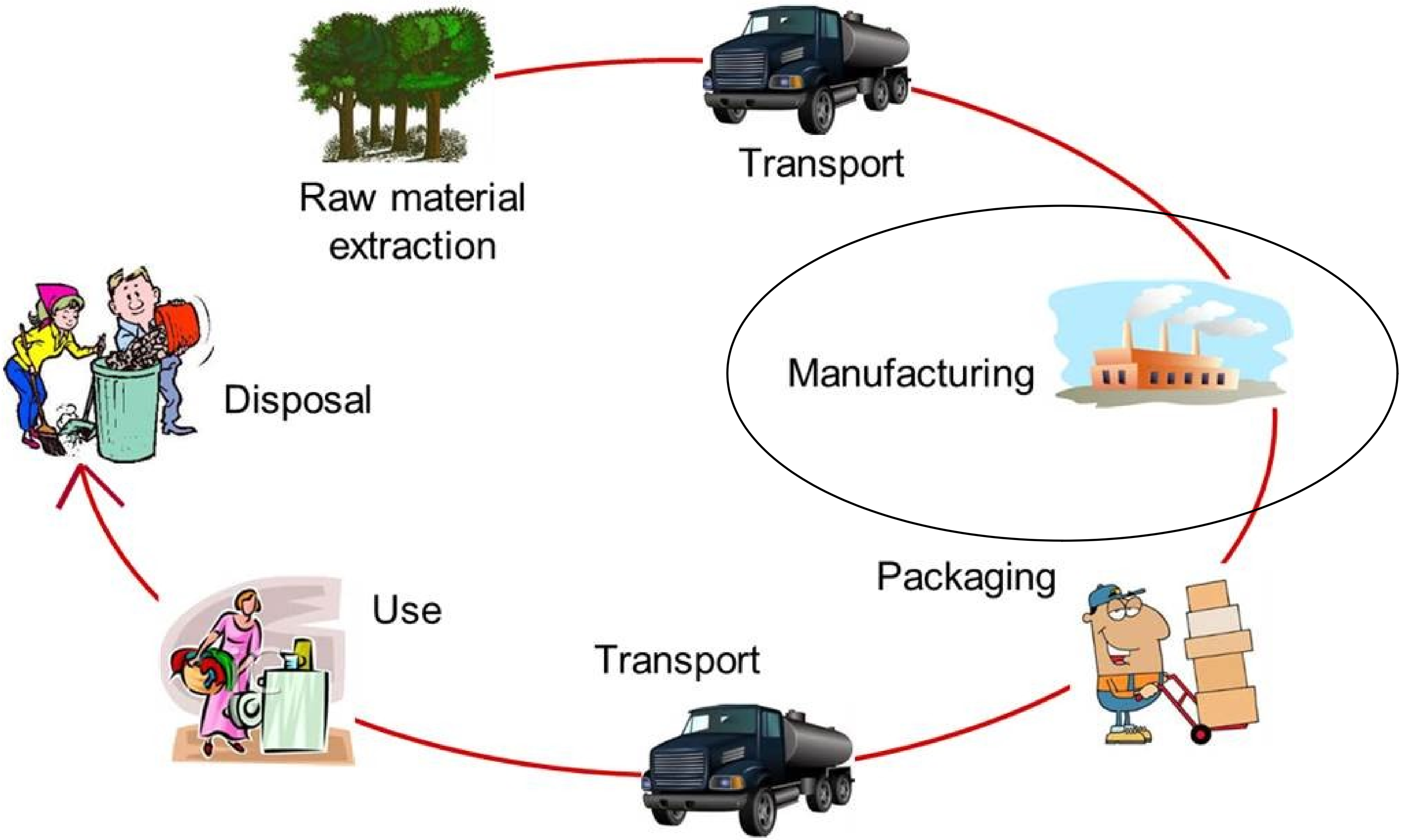
Business and the Environment

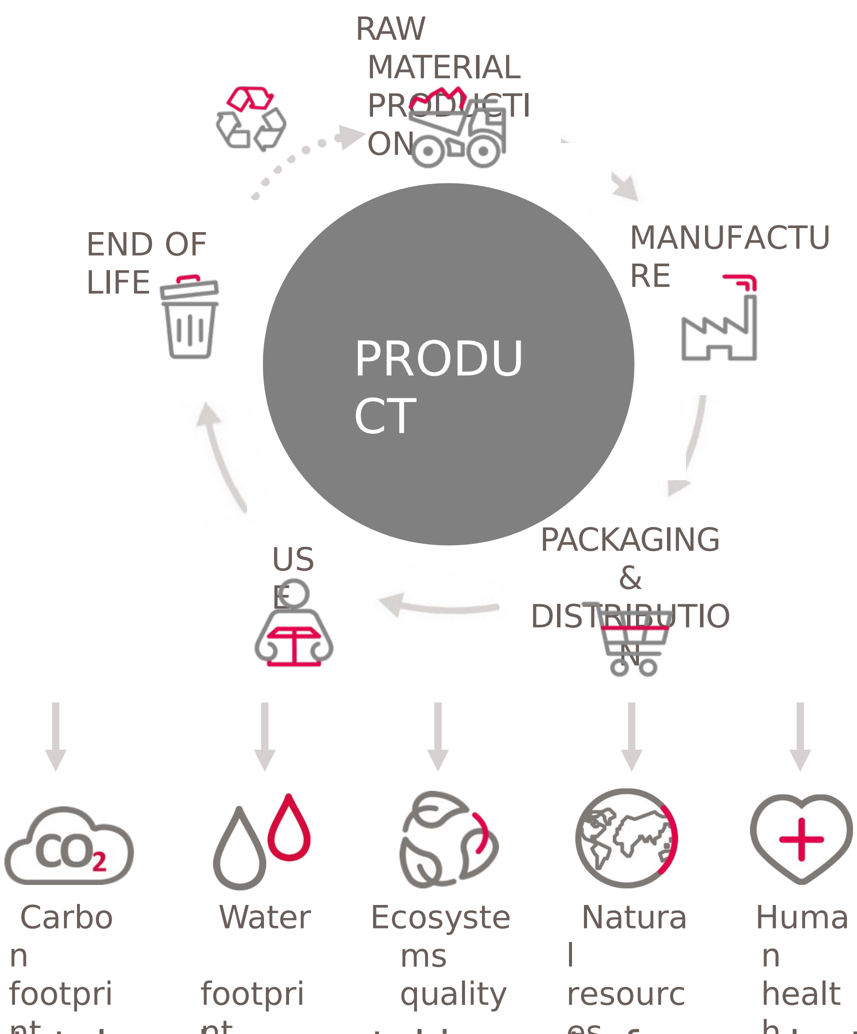
Life Cycle Assessment

Magali Delmas
UCLA

What is a Product Life Cycle?



What is Life Cycle Assessment (LCA)?



An LCA evaluates the total environmental impact of a product over it's entire production (and/or consumption) chain, allowing for a comprehensive comparison of alternative ways of meeting human needs and economic functions.


VS
VS

Who benefits from a Life Cycle Assessment?

Product Development & Research & Development

Complying & Developing Products

Supply Chain Management & Procurement

Evaluating Suppliers

Marketing & Sales

Communicate Competitive Edge

Executive Level & Strategic Management

Avoid Risks, Lead Strategically

LCA for product improvement

- Polyester blouse life-cycle energy requirements
  - Production 18%
  - Use 82%
  - Disposal < 1%
- Energy requirements of use stage could be reduced by more than 90% by switching to cold water wash and line dry instead of warm water and drying in dyer

Planning an LCA project

- Define product under study and its alternatives
  - What is its function?
  - What is an appropriate **functional unit**?

- Choose **system boundaries**
  - What inputs and outputs will be studied?
  - How will data be collected?

The Functional Unit

Functional Unit Ambiguity

Functional unit	12-oz aluminum cans	16-oz. Glass bottle	1-liter PET bottle
12-oz of soft drink	1	1.25	2.7
One container	1	1	1

The Functional Unit

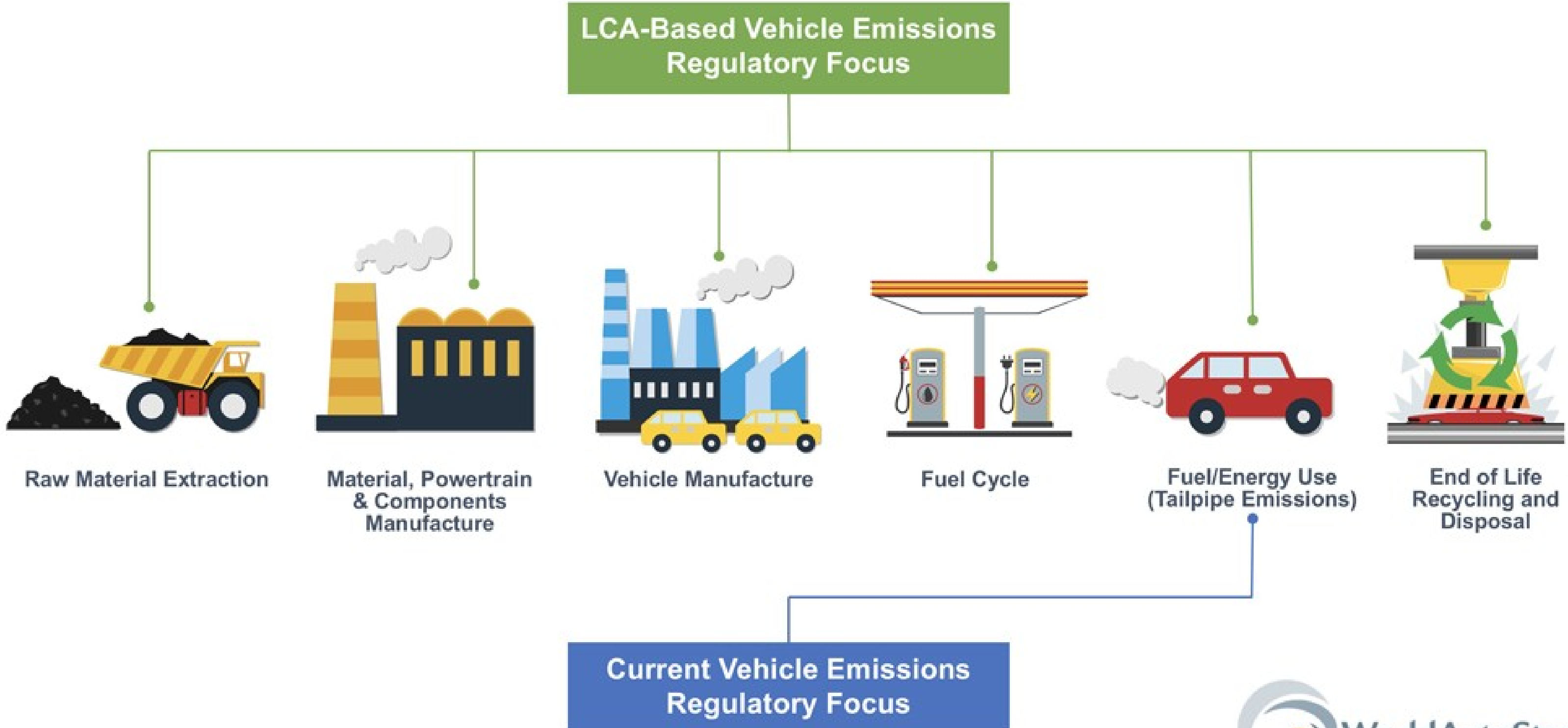
- Example: paper versus Plastic grocery bags
- **Function :** to carry groceries

Functional unit : could be a defined volume of groceries—one plastic bag does not hold the same volume of groceries as a paper bag

System boundaries

System boundaries

- Processes are excluded in order to keep the life-cycle inventory manageable
- For example in the production of ethylene
  - oil has to be extracted, this oil is transported by a tanker, steel is needed to construct the tanker, and the raw materials needed to produce this steel have to be extracted….
- Should the production of capital good be excluded?



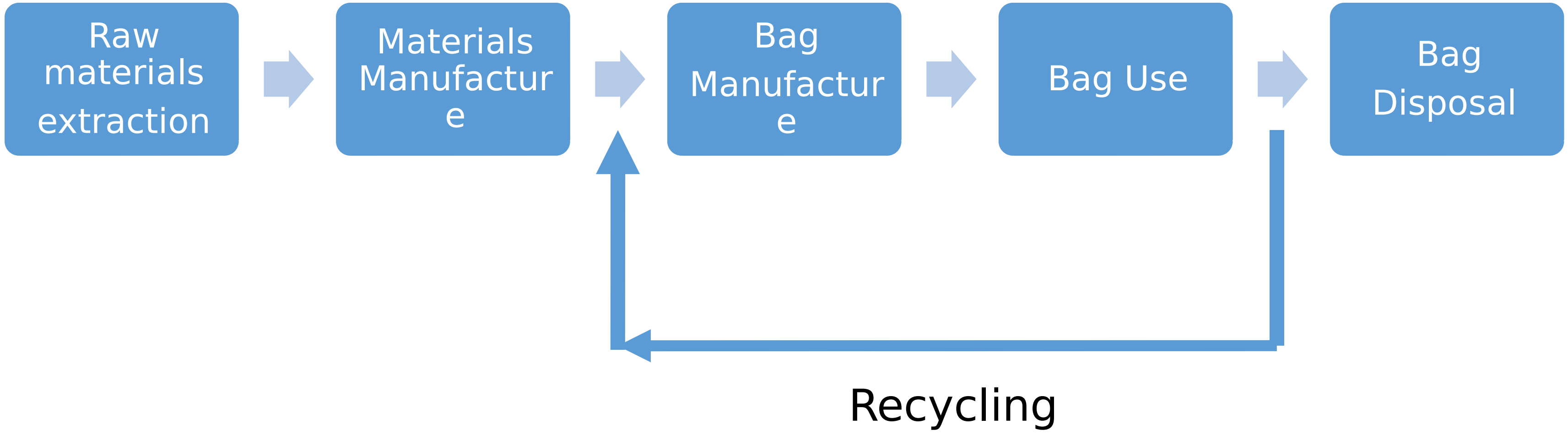
WorldAutoSteel

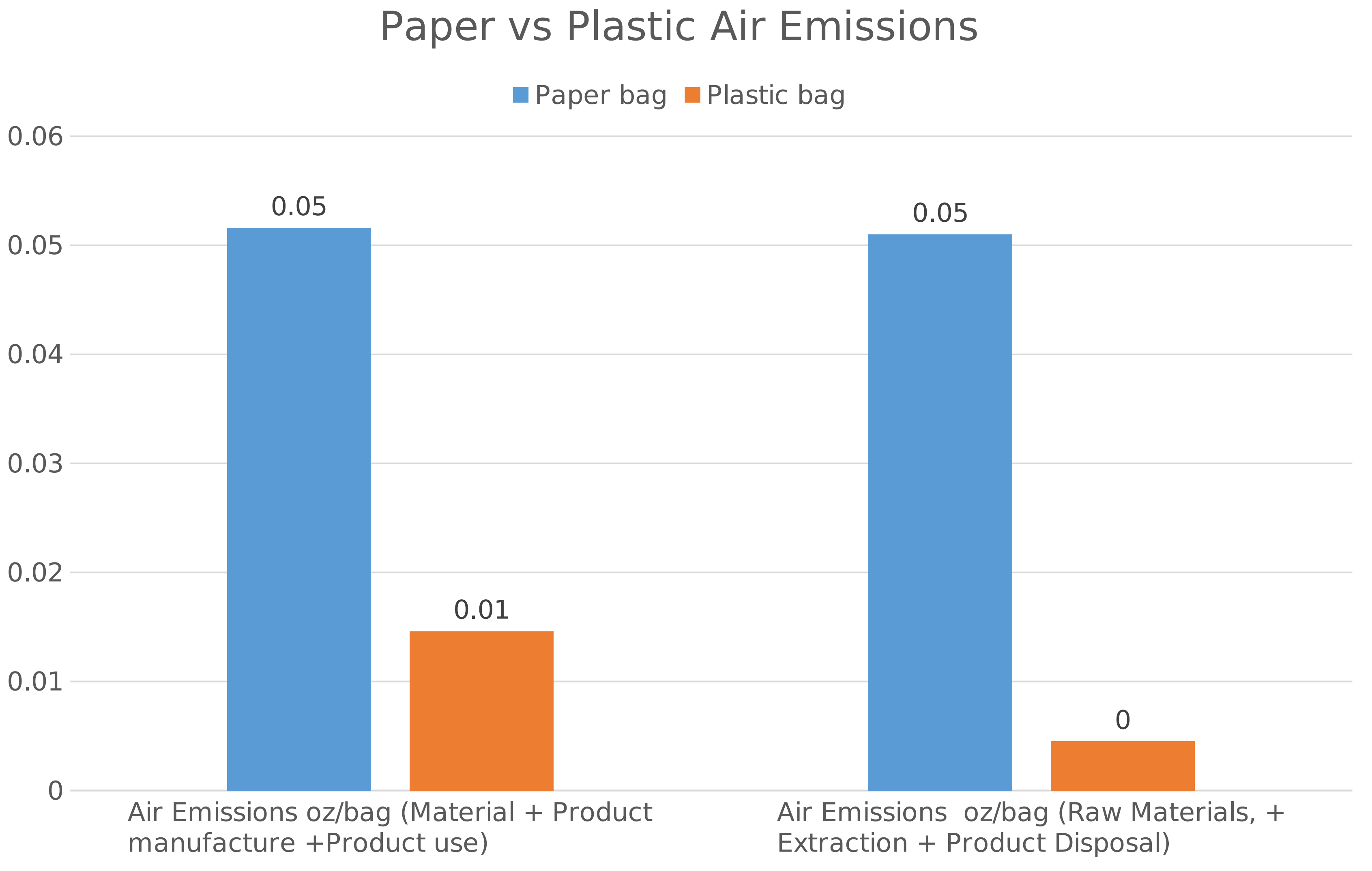
Incandescent, fluorescent and LED light bul

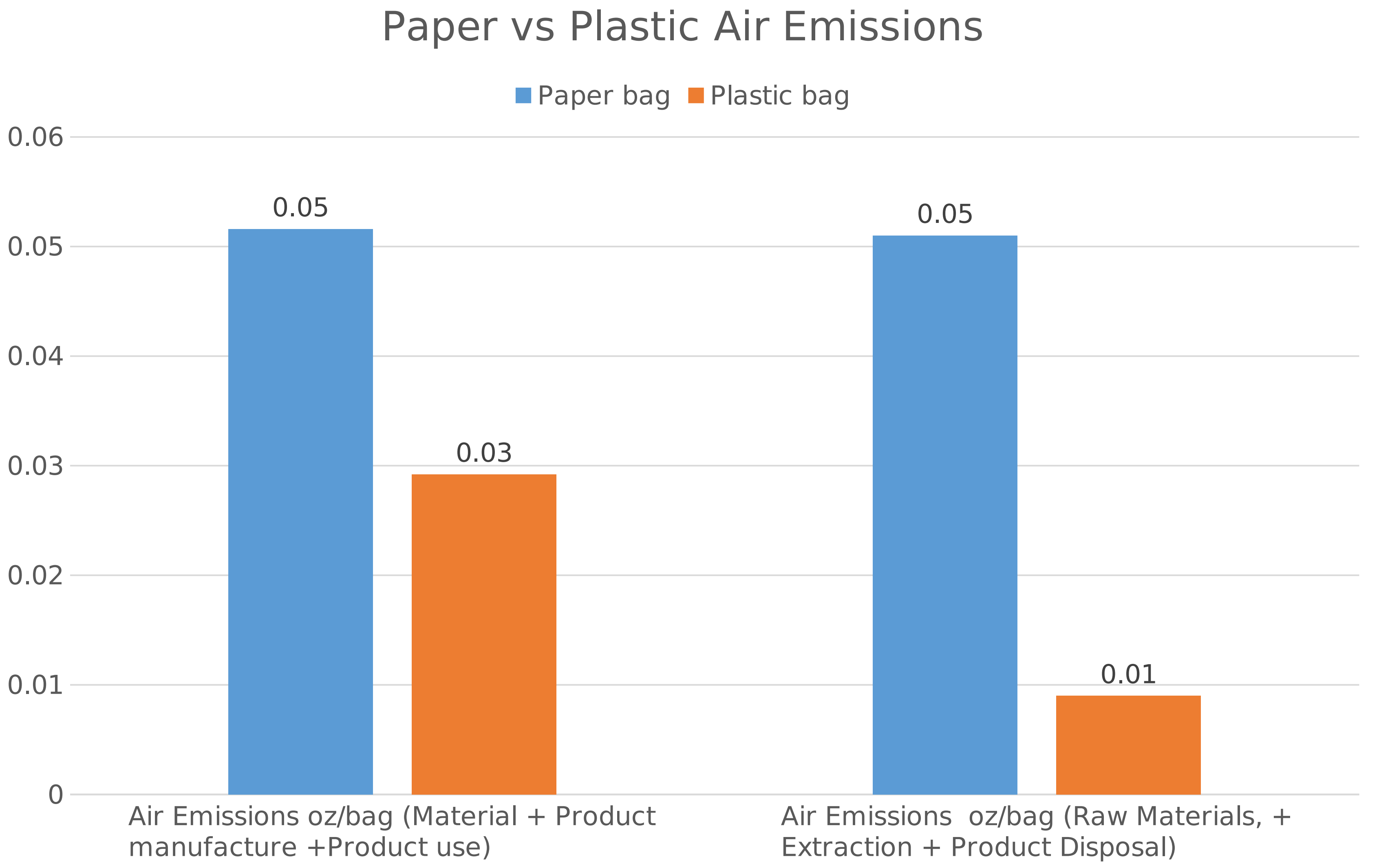
- Incandescent bulbs require more energy to operate
- Fluorescent bulbs provide light by causing mercury to fluoresce. Risk of mercury release during disposal
  - Mercury is a trace contaminant in coal and when coal is burned to generate electricity, some mercury is released to the atmosphere
- Issue of which bulb is better depends on the boundary of the system chosen.
- LEDs? Lead, arsenic see EST

Paper or Plastic

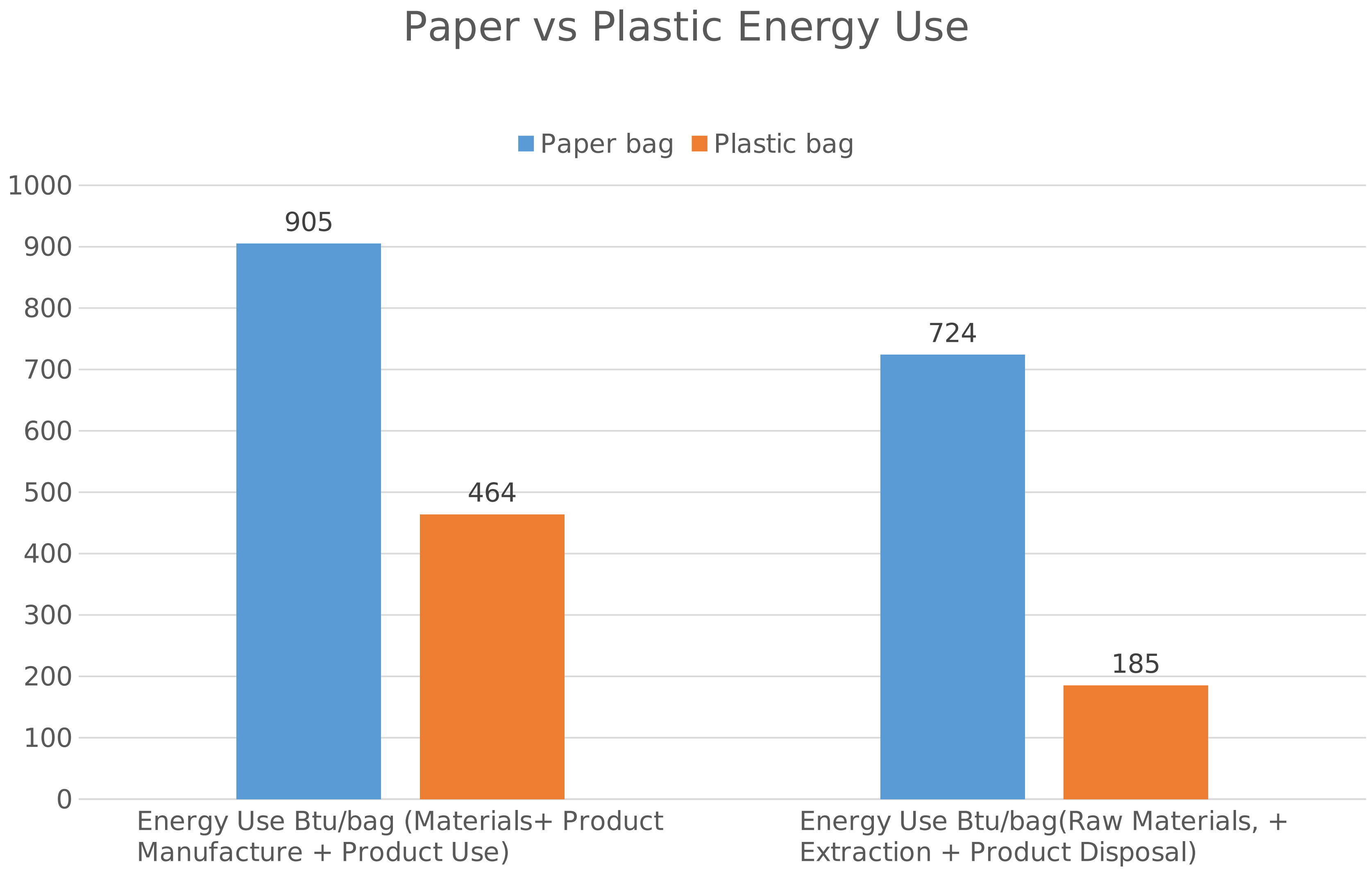
Grocery Bag: Paper or Plastic?




Paper vs Plastic Air Emissions
Paper bag
Plastic bag
0.06
0.05
0.04
0.03
0.02
0.01
0
0.05
0.01
0.05
0
Air Emissions oz/bag (Material + Product manufacture +Product use)
Air Emissions oz/bag (Raw Materials, + Extraction + Product Disposal)



1 paper bag = 2 plastic bags


Paper vs Plastic Energy Use
Paper bag
Plastic bag
1000
900
800
700
600
500
400
300
200
100
0
905
464
724
185
Energy Use Btu/bag (Materials+ Product Manufacture + Product Use)
Energy Use Btu/bag(Raw Materials, + Extraction + Product Disposal)

Steps of LCA

1. Goal and Scope

- Functional Unit
- System Boundaries

2. Inventory Analysis

- Data collection phase of a Life Cycle Assessment
- Quantify the environmental inputs and outputs

3. Impact Assessment

- Evaluating how significant the impacts are (health, biodiversity etc...)

4. Interpretation

- Identifying significant issues and limitations

1) Inventory Data must be combined with effect data before conclusions can be drawn

- Air Emission for production of 1Kg of Polyethylene and Glass:

Emissions (Kg)	**Polyethylene**	**Glass**
Co2 (carbon dioxide)	1.8	0.49
Nox (nitrogen oxide)	0.0011	16
So2 (sulfur dioxide)	0.00099	0.0027
CO (carbon monoxide)	0.00067	0.000057

2) Life Cycle Impact Assessment

Compound specific waste and emission inventory data

+

Information on environmental fate and potency of specific compounds

=

Impact Assessment

Possible impact categories

- Smog formation
- Human carcinogenicity
- Aquatic toxicity
- Terrestrial toxicity
- Global warming
- Acidification
- Stratospheric ozone depletion

- **How to aggregate these impact categories?**
- **How to assign weights?**

Steps for Life Cycle Impact Assessment

- 1. Selection and definition of impact categories
- 2. Classification
  - Assigning LC Inventory results to the impact categories (e.g. CO_2 emissions to global warming)
- 3. Characterization
  - Modeling LC Inventory impacts within impact categories using **science-based conversion factors** (e.g. modeling the potential impact of CO_2 and methane on global warming)
- 4. Normalization
  - Expressing potential impacts in ways that can be compared (e.g. comparing the global warming of CO_2 and methane for the two options. Finding a reference value)

6. Weighting

- Emphasizing the most important potential impacts

How ?

The Environmental Product Strategies (EPS) system

- Environmental indices are multiplied by the appropriate quantity of raw material used or emissions released to arrive at **Environmental Load Units (ELUs),** which can then be added together to arrive at an overall ELU
- Valuation based on impact on health that is measured as a $ amount based on willingness- to-pay surveys
- Provide a $ amount on negative externality

See **About the EPS impact assessment method**
The EPS 2015 impact assessment method – An overview

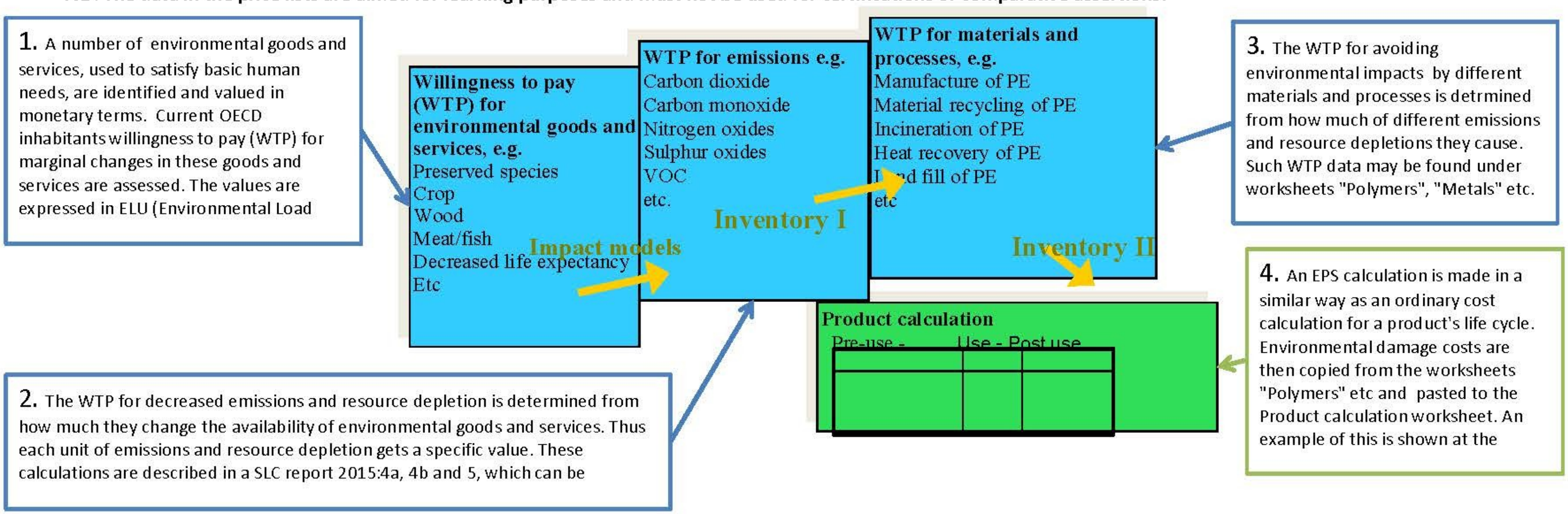
SWEDISH LIFE CYCLE CENTER

EPS - Environmental Priority Strategies in Product Design

EPS is a tool for calculation of a product's environmental damage cost during its life cycle.

The calculation is made by means of a price list on the environmental damage costs for different materials and processes. The price list is developed as shown in 1-3 below.

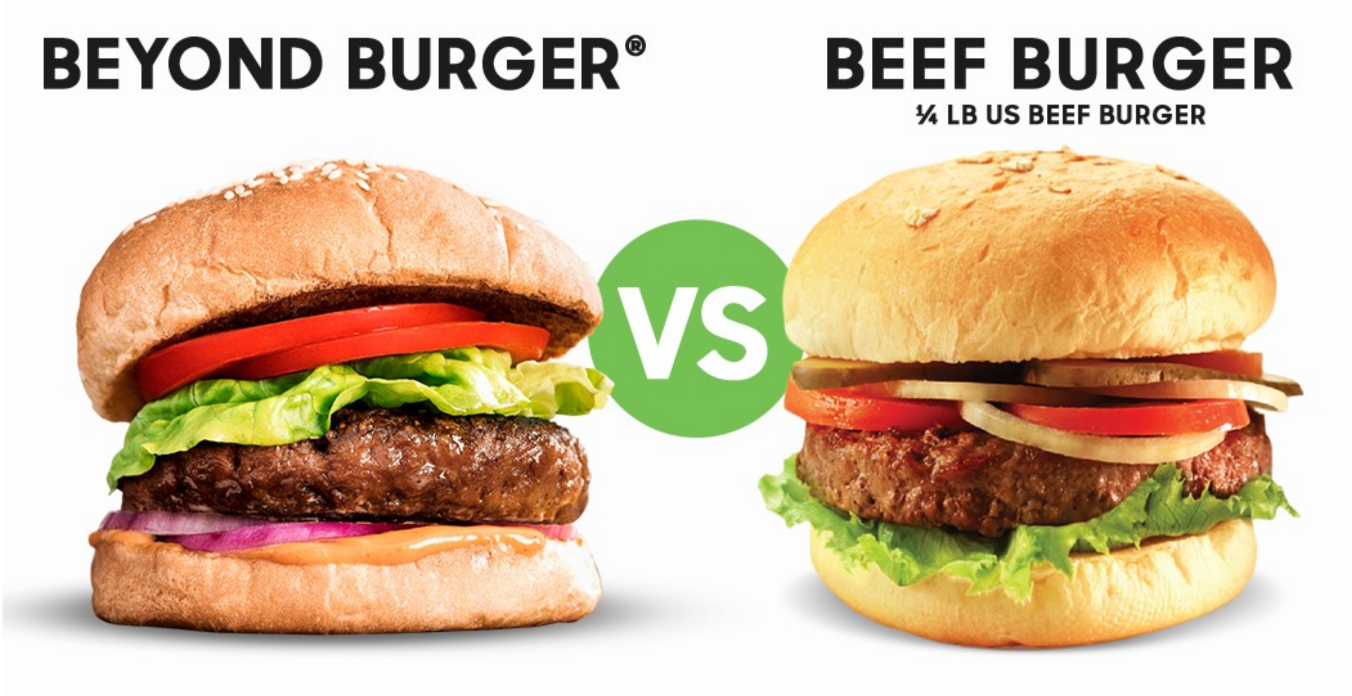
NB: The data in the price lists are aimed for learning purposes and must not be used for certifications or comparative assertions.



https://www.lifecyclecenter.se/

Other methods

- Critical volumes
  - Emissions are weighted based on legal limits and are aggregated within each environmental medium (air, water, soil)
- Distance to target
  - Valuation based on target values for emission flows set in the Dutch national environmental plan
- Ecological scarcities
  - Valuation based on flows of emission and resources relative to the ability of the environment to assimilate the flows or the extent of resources available


BEYOND BURGER®
VS
BEEF BURGER
¼ LB US BEEF BURGER

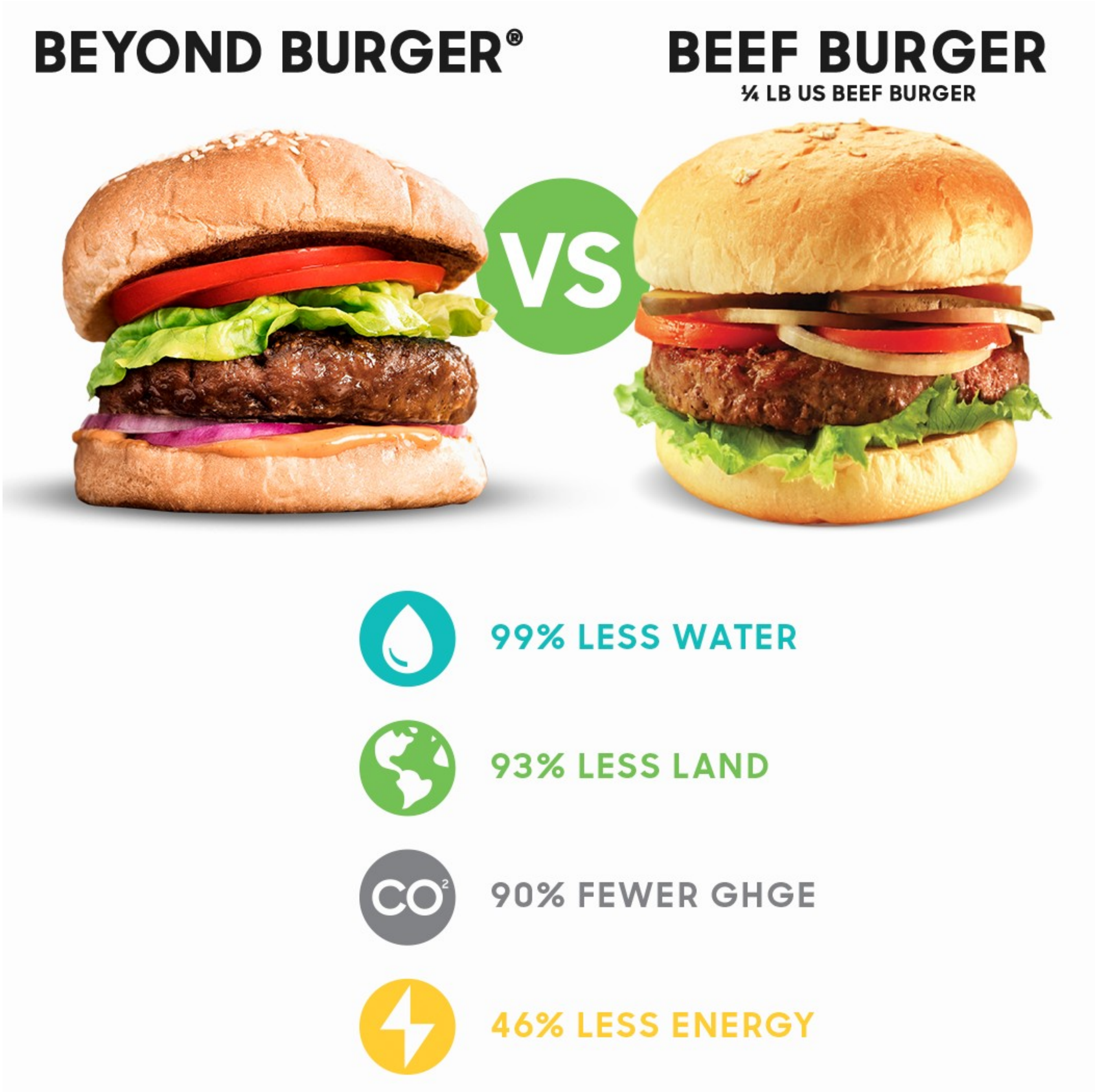
Beyond LCA: Functional unit & System boundaries

Functional Unit 4 oz. (quarter pound, 0.113 kg) uncooked burger patty delivered to retail outlets

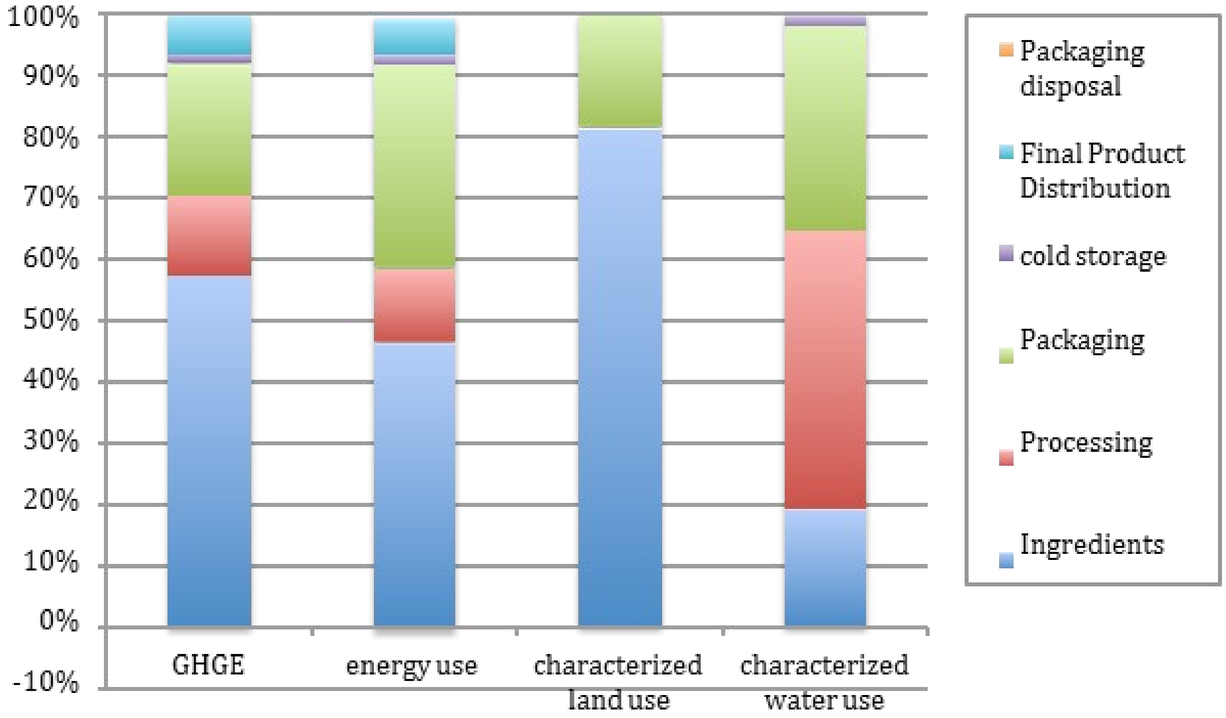
Nutritional comparison BB patty and 80/20 beef

	4 oz. BB patty	4 oz. 80/20 beef (USDA, 2015)
Protein (g)	20	19
Iron (DV)	25%	12%
Saturated fat (g)	5	9
Cholesterol (mg)	0	80
Total fat (g)	22	23
Calories	290	287

System boundaries: upstream ingredient and raw material supply (including farm production of agricultural crops), processing and packaging operations, cold storage, distribution to point of sale, and disposal of packaging materials. (Retail not included)


BEYOND BURGER®
BEEF BURGER
¼ LB US BEEF BURGER
VS
99% LESS WATER
93% LESS LAND
CO2
90% FEWER GHGE
46% LESS ENERGY

Distribution of impacts across life cycle stages for the Beyond Burger.



Impossible burger

IMPACT CATEGORY	UNIT	IMPOSSIBLE™ BURGER	BEEF BURGER	DIFFERENCE
Aquatic Eutrophication Potential	g PO4-eq	1.3	15.1	-92%
Global Warming Potential	kg CO2-eq	3.5	30.6	-89%
Land Occupation*	m2.y	2.5	62.0	-96%
Water Consumption	liters	106.8	850.1	-87%

**Land occupation is reported at an LCI level. Based on best available LCA-related information on food production, in accordance with ISO 14044 standard*

https://impossiblefoods.com/sustainable-food/burger-life-cycle-assessment-2019

Beyond Meat

- LCA used for marketing purposes
- Watch video:
- https://www.beyondmeat.com/whats-new/a-burger-with-benefits/
- 1m35s

+ Regenerative grazing is a management practice that accounts for the optimal resting time of the land to prevent overgrazing and allow regeneration of degraded land.

+ White Oak Pastures (WOP) practices regenerative grazing to regenerate degraded cropland and convert it to permanent pasture

  + Here, we've assessed the carbon footprint of beef from WOP and made comparisons to evidence about the carbon footprint of conventional US beef.

CARBON FOOTPRINT EVALUATION OF REGENERATIVE GRAZING AT WHITE OAK PASTURES

RESULTS PRESENTATION

Prepared for:

General Mills
Making Food People Love

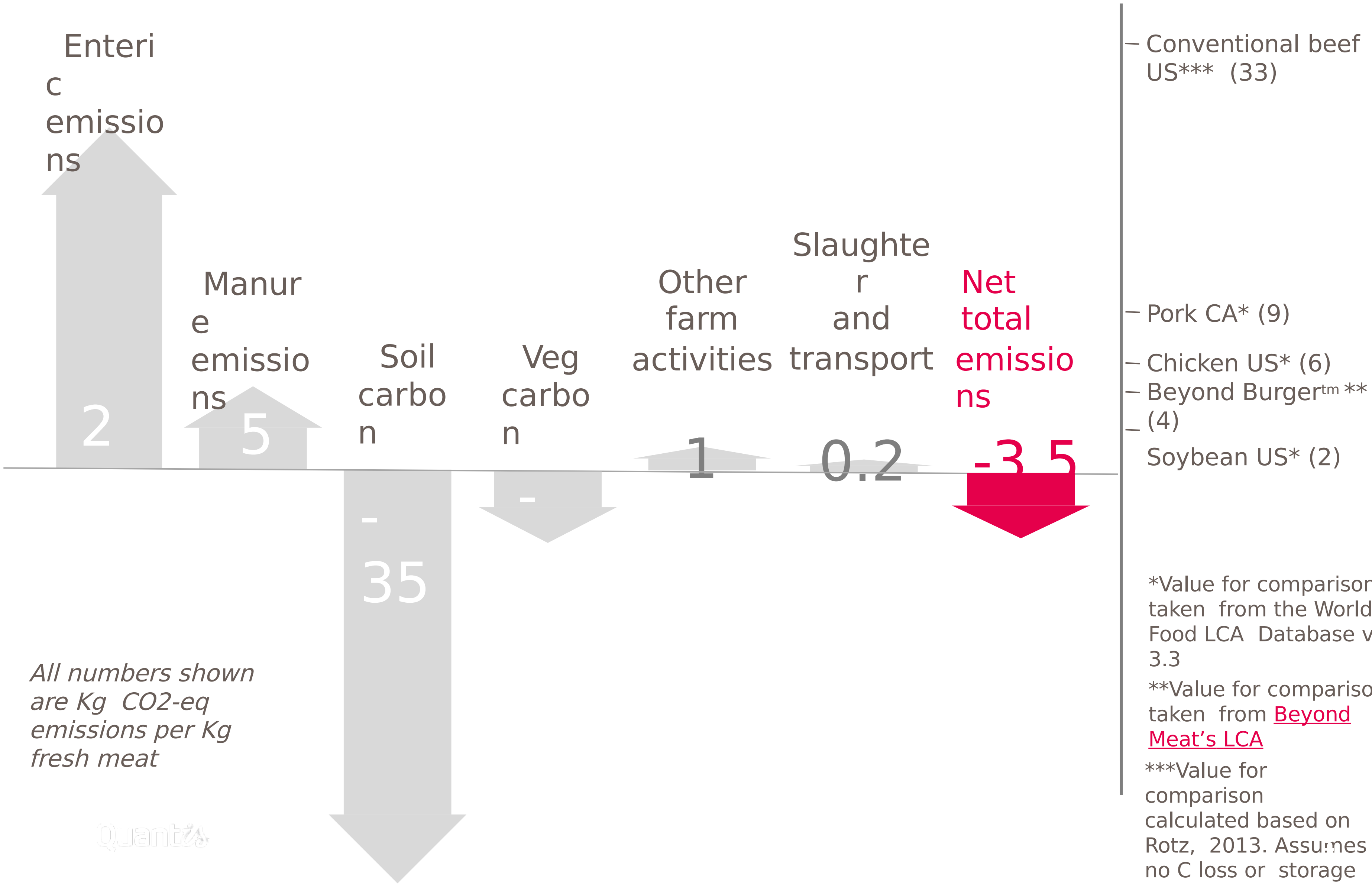
+

WHITE OAK PASTURES
EST. 1866
BLUFFTON, GEORGIA

MARIKO THORBECKE
Sustainability Consultant mariko.thorbecke@quantis-intl.com

JON DETTLING
Global Director, Services + Innovation
jon.dettling@quantis-intl.com

Carbon footprint breakdown per kg of White Oak Pastures' beef



All numbers shown are Kg CO2-eq emissions per Kg fresh meat

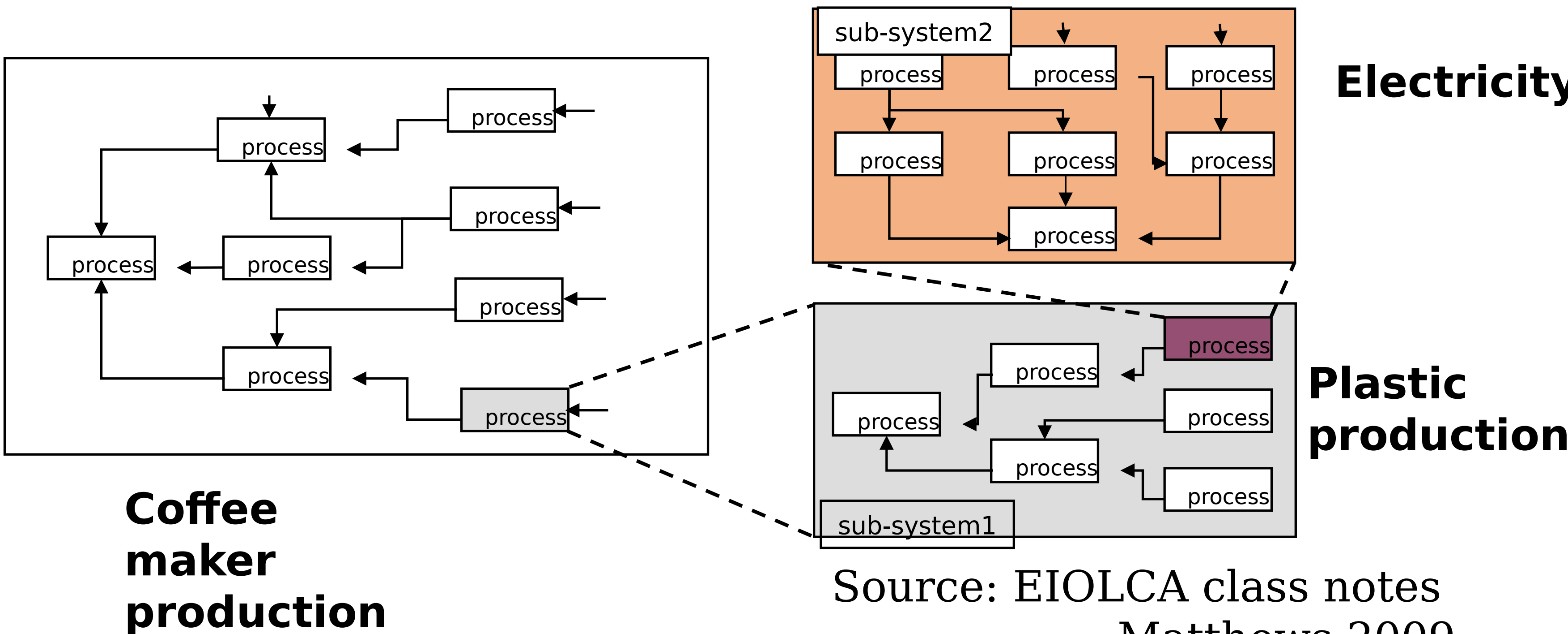
*Value for comparison taken from the World Food LCA Database v. 3.3

**Value for comparison taken from Beyond Meat's LCA

***Value for comparison calculated based on Rotz, 2013. Assumes no C loss or storage in cow-calf stage

Process based LCA structure

BUT There are complete life cycle phases associated with each of the input items for a coffee maker as well



Source: EIOLCA class notes
Matthews 2009

Economic Input-Output Analysis

- Developed by Wassily Leontief (Nobel Prize in 1973)
- “General interdependency” model: quantifies the interrelationships among sectors of an economic system
- Identifies the direct and indirect economic inputs of purchases
- Creates a picture of a regional economy describing flows to and from industries
- Can be extended to environmental and energy analysis

Input-Output method

- An input/ouput table quantifies the transactions between sectors of an economy
- Input-output model divides entire economy into distinct sectors
  - Set of large tables or matrices with 480 rows and 480 columns
- Each sector represented by one row and one column
- Economic input-output model is linear. That means a $100 purchase from a sector would be ten times greater than a $10 purchase from same sector
  - If you buy 1 kg of a product from a sector for $10 then buying 10 kg would cost $100

Economic Input-Output Life Cycle Assessment (EIO-LCA)

- To produce a product in one sector, inputs from many different other sectors are required
  - To make cheese: need \$x of transportation, \$y of dairy production, \$z electricity
- Each sector has environmental sector impacts per output, tabulated,
  - eg., 20kg CO_2eq/\$ dairy production output
- The overall environmental impact for a product or service:

Impact/product = Σ (sector inputs in \$ needed to make the product) x (the sector impact/\$)

The Boundary Issue

- Process-Based LCA: include **all direct processes** for evaluating a single product
  - for making electricity must choose carefully the boundary of processes included, e.g. is coal transportation included?
  - Sometimes the boundary to choose is not clear

- In EIO-LCA, the boundary is by definition the entire economy, recognizing interrelationships among industrial sectors
- In EIO LCA, the products described by a sector are representing an **average** product not a specific one

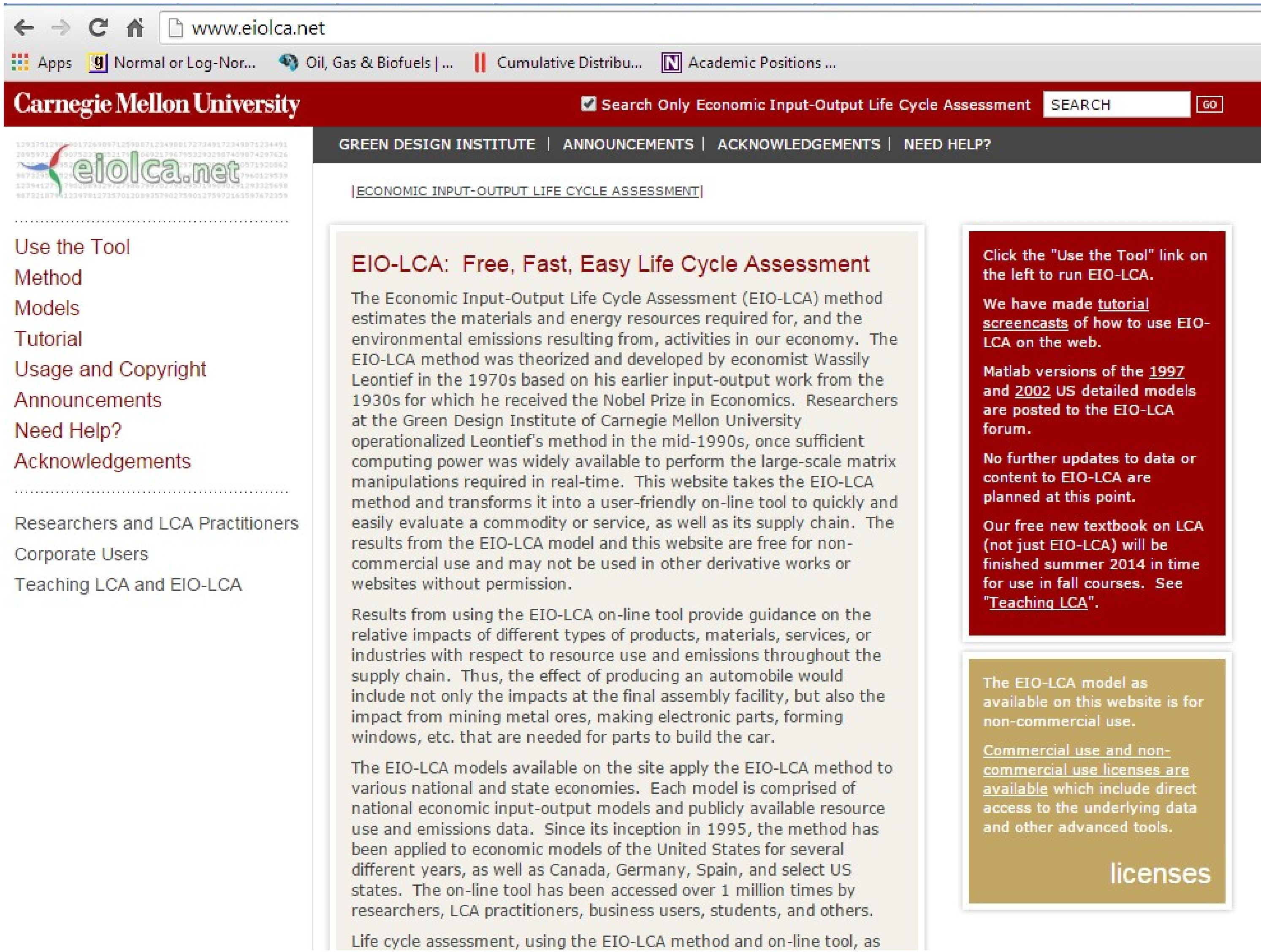
Data Sources in EIO-LCA

Data	**Source**
Economic input-output matrix	U.S. Dept. of Commerce
Electricity consumption	U.S. Dept. of Commerce
Fuel use	U.S. Dept. of Commerce
Toxic chemical emissions (TRI)	U.S. EPA's TRI database
Conventional air pollutant emissions	U.S. EPA's AIRS database

Example of using EIO-LCA

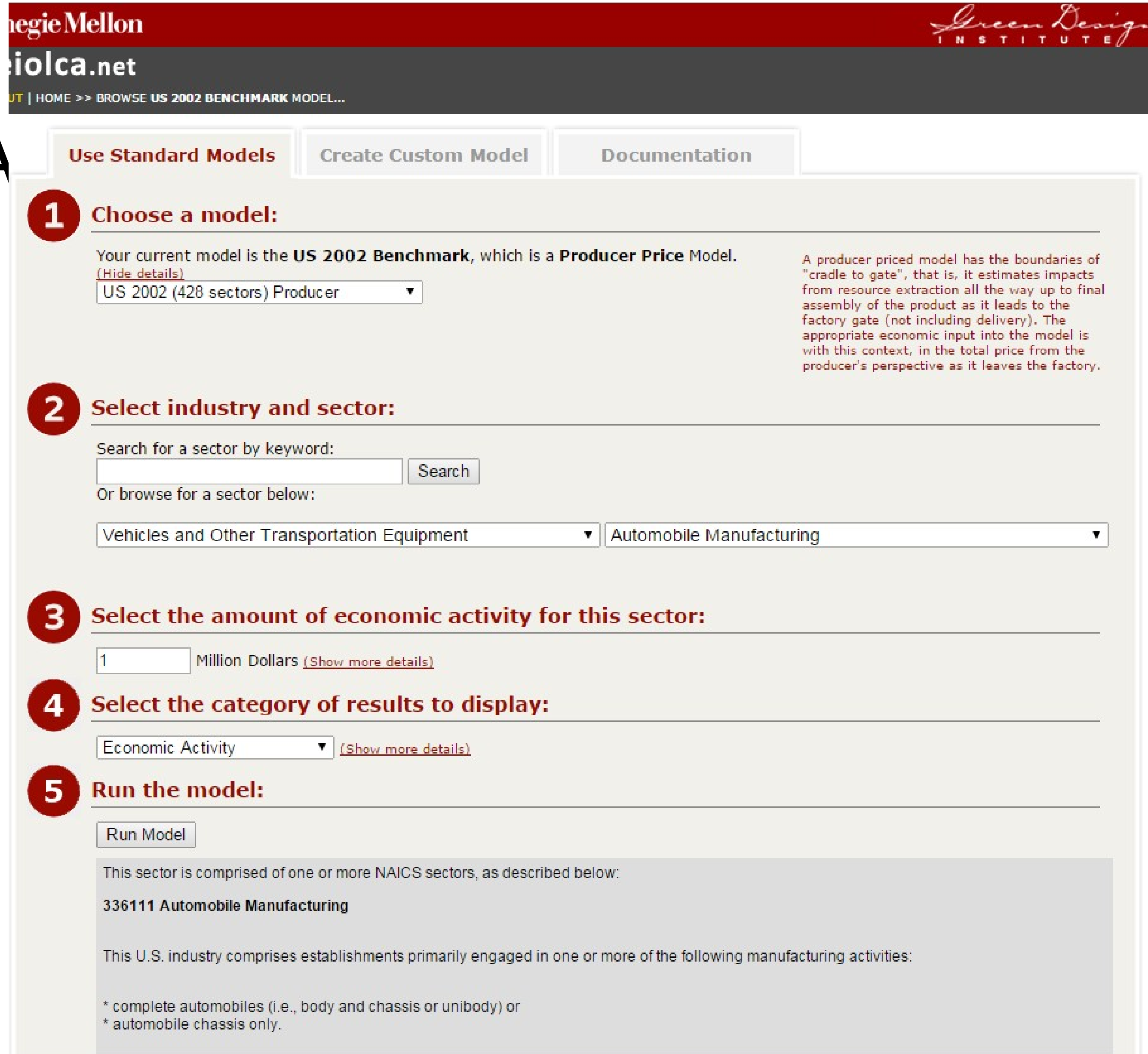
- As defined by US Department of Commerce, The Vehicle and other Transportation Equipment Industry contains the Automobile manufacturing sector
- We will trace through production of $1 million of automobiles manufactured in 2002.
- www.eiolca.net

EIOLCA tool



http://www.eiolca.net/cgi-bin/dft/use.pl

Steps to use EIO-LCA



Total economic output of $1 million automobile manufacturing

Need cars to make cars

Service sectors also represent ed

Sector	Total Economic $mill ↑
Total for all sectors	2.71
Automobile Manufacturing	0.849
Motor vehicle parts manufacturing	0.506
Light Truck and Utility Vehicle Manufacturing	0.15
Wholesale trade	0.124
Management of companies and enterprises	0.108
Iron and steel mills	0.038
Semiconductor and related device manufacturing	0.026
Truck transportation	0.025
Other plastics product manufacturing	0.021
Power generation and supply	0.02

Top 10 sectors only presented here. Download excel file: 428 sectors

Total conventional air pollutants output of $1 million automobile manufacturing

A lot of iron and steel required for automobiles

Some sectors which would have not shown up in traditional process based LCA results

Sector	CO	NH3	NOx	PM10	PM2.5	SO2	VOC
	t	t	t	t	t	t	t
Total for all sectors	2.52	0.119	1.46	0.478	0.196	1.47	0.757
Iron and steel mills	0.538	0.002	0.081	0.022	0.018	0.06	0.018
Alumina refining and primary aluminum production	0.29	0	0.013	0.009	0.006	0.092	0.004
Truck transportation	0.2	0	0.211	0.06	0.011	0.004	0.022
Motor vehicle parts manufacturing	0.178	0.001	0.032	0.007	0.005	0.017	0.047
Carbon black manufacturing	0.124	0	0.01	0.002	0.001	0.066	0.003
Natural gas distribution	0.083	0	0.004	0	0	0.001	0.004
Iron, steel pipe and tube manufacturing from purchased steel	0.077	0	0.011	0.004	0.003	0.009	0.005
Commercial and industrial machinery and equipment rental and leasing	0.067	0	0.001	0	0	0	0.005
Wholesale trade	0.062	0	0.061	0.017	0.003	0.004	0.033
Household goods repair and maintenance	0.053	0	0	0	0	0	0.004

Headline represent emissions of CO, NH3, NOx, PM10, PM2.5, SO2, VOC from each sector

Top 10 sectors only presented here

Necessity of EIO-LCA

- Process-based LCA are time consuming
- EIO-LCA may be used as a quick approximation tool
  - Hypothesis- each $ of production or TJ of product uses the same amount of energy and resources and results in the same pollution discharge

Sector	Computers	Automobiles	Shoes
Air pollutants per $1M (metric tons)	6.2	15	13
Air pollutants per TJ of petroleum (metric tons)	4.0	4.3	4.0
Toxic discharges per $1M (metric tons)	32	2.0	1.1
Toxic discharges per TJ of petroleum (metric tons)	2.1	0.59	3.5

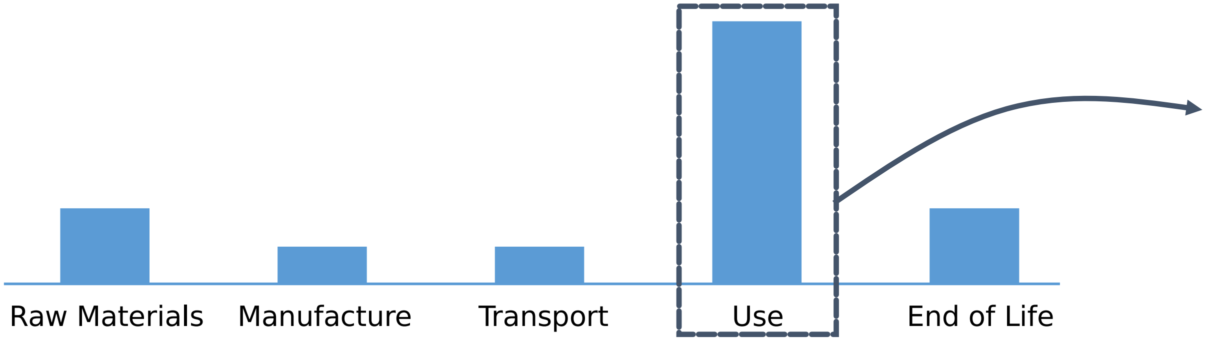
Source: Modified from Hendrickson et al (2006)

Large ranges across sectors. Service sectors cannot be estimated by this. The approximations are not a good replacement for a thorough life cycle assessment. However, it is a quick and easy tool to understand some of the underlying life cycle impacts

	Process model	EIO-LCA
+	**Detailed analysis of specific processes**	**Boundary is defined as the entire economy**
	Product comparisons	Economy-wide, system LCA
	Identify process improvements	**Publicly available data**
		Reproducible results
–	**Subjective boundary selection**	**Aggregated level of data**
	Lack of comprehensive data in many cases	**Identification of process improvements are difficult**
	Time and cost intensive	Imports treated as United States products
	Proprietary data	Uncertainty
	Uncertainty	Limited non-United States data
		Product use and end-of-life options not included

3) Life-cycle improvement and analysis

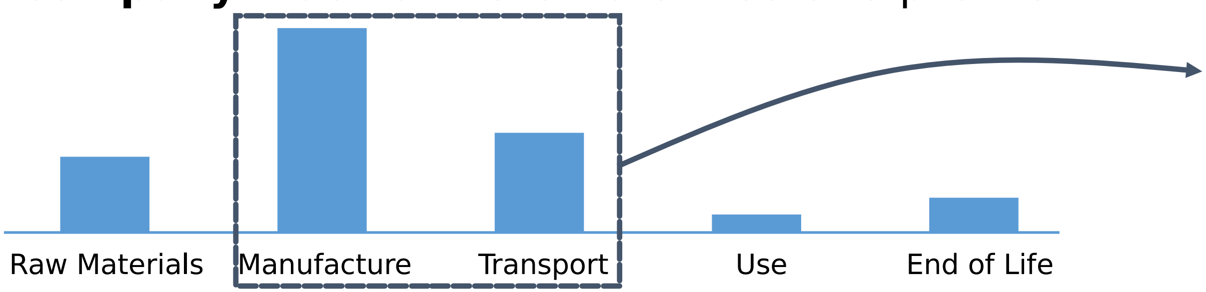
er products company illustrative GHG emissions profile



Greatest GHG impact from the use of products.

They **may focus on methods or products that enable consumers** to reduce

cal company illustrative GHG emissions profile



Greatest GHG impact from the production and distribution of their products.

They **may choose to work to improve their manufacturing and transportation processes** to reduce GHG emissions.

Where to focus the eff

- Allows us to focus on the most **significant environmental impacts** as we develop and evaluate sustainability programs and policies
- Informs product decisions to reduce the environmental impact from **design,** materials, and manufacturing
- Supports engagement with **external stakeholders** to reduce the impact of materials and consumer care

See resulting environmental impact information from our first 11 products here. For more detailed information about our product assessments, download our study.

- Levi's® 501® Original Jeans – Rinse Run
- Levi's® 501® Original Jeans – Dark Stonewash
- Levi's® 501® Original Jeans – Medium Stonewash
- Levi's® 501® Original Jeans – Light Stonewash
- Slim Straight 514™ Jeans – Indigo Wash
- Slim Straight 514™ Jeans – Tumbled Rigid
- Regular Straight 505® Jeans – Range (less water)
- Regular Straight 505® Jeans – Range
- Slim Straight 514™ Jeans – Rigid Tank
- Regular Straight 505® Jeans – House Cat
- Regular Straight 505® Jeans – Steel (less water)

REGULAR STRAIGHT 505® JEANS

RANGE (LESS WATER) (PC9 00505-2765)

IMPACT CATEGORY	QUANTITY
GLOBAL WARMING POTENTIAL	16 Kg CO2 - equivalents
ENERGY USE	190 Megajoules
RENEWABLE ENERGY	13%
WATER USE	5.9 Cubic meters
LAND OCCUPATION	6.6 Square meter x year
QUALIFIED SUSTAINABLY GROWN FIBER	0%
PRIMARY WASTE	0.10 Kg
MATERIALS EFFICIENCY	87%
RECYCLED CONTENT	1%
EUTROPHICATION	0.004 Kg Phosphorous - equivalents
LAND TRANSFORMATION	0.002 Square meters

Combining LCA and Life-cycle Cost Analysis (LCC)

- Which modifiable process or product design variable with the system provide the greatest combined economic and environmental advantage?

- What are the incremental costs of environmental improvement for each option, and which provides the greatest environmental improvement per $?

- How low must the investment cost be for a particular environmental improvement to become cost effective?

McDonald's Clamshell or quilt-wrap?

	Polystyrene clamshell	Quilt-wrap
Recycling	Problematic	No recycling
Cost	2 to 2.5 cents/sandwich	1.5 to 2 cents/sandwich
PR	Bad	Good
Landfill space	High	25% less than polystyrene
Atmospheric emissions	13.8 lbs/sandwich	9.7 lbs/sandwich
Waterborne wastes	2.5 lbs/sandwich	1.4 lbs/sandwich

Uses of Life Cycle Studies

- Product comparison
- Strategic Planning/ DfE
- Public Sector Uses/ Eco-labels
- Marketing

Softwares

- EPA website
  - http://www.epa.gov/ORD/NRMRL/lcaccess/resources.htm#Software
- GaBi
  - http://www.gabi-software.com/
- Simapro
  - http://www.pre.nl/default.htm

Conclusion

- LCA examine the environmental impact of a process or product
- Important uses: DfE, Eco labels, Differentiation strategy
- Number of difficulties. In particular, impacts may be difficult to evaluate and compare
- Important to combine LCA with LCC

Additional Slides

Example:

Transactions Table forms the basis for the I-O Model

Sectors of our economy purchasing and producing our stuff

Demand from households, government, export.

Can also be explained as demand of goods not used to produce other goods

Processing Sectors	Purchasing Sectors			Final Demand	Total Output
	Agriculture	Forest Products	Manufacturing		
Agriculture	8	4	4	20	36
Forest Products	7	9	5	11	32
Manufacturing	4	2	4	24	34
Value Added	11	15	13		39
Imports	6	2	8		16
Tot Out			34	55	157

Value added is income earned in production including labor earnings
Eg- compensation, taxes

Source: Eric McConnell 2014 presentation

Total economic output of $1 million automobile manufacturing

Need cars to make cars

Service sectors also represented

Sector	Total Economic $mill ↑	Total Value Added $mill	Employee Comp VA $mill	Net Tax VA $mill	Profits VA $mill	Direct Economic $mill	Direct Economic %
Total for all sectors	2.71	0.971	0.56	0.042	0.368	1.74	64.2
Automobile Manufacturing	0.849	0.21	0.073	0.002	0.135	0.849	100
Motor vehicle parts manufacturing	0.506	0.15	0.114	0.003	0.033	0.446	88.1
Light Truck and Utility Vehicle Manufacturing	0.15	0.031	0.013	0	0.018	0.15	99.9
Wholesale trade	0.124	0.086	0.047	0.02	0.019	0.057	46.1
Management of companies and enterprises	0.108	0.067	0.056	0.002	0.009	0.033	30.9
Iron and steel mills	0.038	0.01	0.008	0	0.003	0	1.6
Semiconductor and related device manufacturing	0.026	0.012	0.005	0	0.007	0.014	54.7
Truck transportation	0.025	0.011	0.008	0	0.003	0.009	34.2
Other plastics product manufacturing	0.021	0.008	0.006	0	0.002	0.01	48.5
Power generation and supply	0.02	0.014	0.004	0.002	0.007	0.002	10.7

Top 10 sectors only presented here. Download excel file: 428 sectors

Total GHG output of $1 million automobile manufacturing

Sector	Total	CO2 Fossil	CO2 Process	CH4	N2O	HFC/PFCs
	t CO2e	t CO2e	t CO2e	t CO2e	t CO2e	t CO2e
Total for all sectors	563	412	81.4	41.9	13	14.5
Power generation and supply	180	177	0	0.488	1.1	1.14
Iron and steel mills	108	40.7	66.5	0.657	0	0
Truck transportation	24.1	24.1	0	0	0	0
Oil and gas extraction	20.4	5.75	3.74	10.9	0	0
Cattle ranching and farming	12.4	0.815	0	7.07	4.55	0
Other basic organic chemical manufacturing	11.3	10.1	0	0	1.16	0
Petroleum refineries	11.1	11.1	0	0.035	0	0
Motor vehicle parts manufacturing	10.9	10.9	0	0	0	0
Automobile Manufacturing	10.8	10.8	0	0	0	0
Alumina refining and primary aluminum production	10.7	2.42	3.79	0	0	4.46

Most sectors contributing to GHG emissions are intuitive. But some like cattle ranching and farming contributing to total GHG emissions are not intuitive

Top 10 sectors only presented here

Total energy output of $1 million automobile manufacturing

Sector	Total Energy	Coal	NatGas	Petrol	Bio/Waste	NonFossElec
	TJ	TJ	TJ	TJ	TJ	TJ
Total for all sectors	8.33	2.56	2.63	1.29	0.435	1.41
Power generation and supply	2.19	1.6	0.467	0.078	0	0.051
Iron and steel mills	1.25	0.743	0.341	0.012	0.005	0.151
Motor vehicle parts manufacturing	0.46	0.005	0.19	0.014	0.024	0.228
Automobile Manufacturing	0.381	0.004	0.19	0.013	0.04	0.133
Truck transportation	0.327	0	0	0.324	0	0.003
Other basic organic chemical manufacturing	0.259	0.032	0.099	0.036	0.078	0.014
Petroleum refineries	0.187	0	0.05	0.121	0.009	0.007
Alumina refining and primary aluminum production	0.172	0	0.046	0.001	0.004	0.12
Plastics material and resin manufacturing	0.169	0.007	0.088	0.037	0.018	0.019
Paperboard Mills	0.161	0.015	0.033	0.007	0.095	0.011

Headlines represent the total energy used by each sector from coal, natural gas, petrol, biomass/waste and non fossil fuel sources

Top 10 sectors only presented here

Total hazardous waste generated from $1 million automobile manufacturing

Sector	Haz Waste Gen st
Total for all sectors	416000
Other basic organic chemical manufacturing	107000
Motor vehicle parts manufacturing	106000
Iron and steel mills	49500
Petroleum refineries	41900
Semiconductor and related device manufacturing	21400
Plastics material and resin manufacturing	20400
Automobile Manufacturing	13400
Wholesale trade	11200
Coating, engraving, heat treating and allied activities	7000
Waste management and remediation services	5820

Some service sectors such as wholesale trade show up in the hazardous waste generation.

Top 10 sectors only presented here

Total toxic releases output of $1 million automobile manufacturing

Sector	Fugitive	Stack	Total Air	Surface Water	U'ground Water	Land	OffSIte	POTW Metal	POTW Nonmetal
	kg	kg	kg	kg	kg	kg	kg	kg	kg
Total for all sectors	27.7	151	178	25.8	22.4	357	162	1.79	46.9
Automobile Manufacturing	4.73	44	48.7	0.009	0	0.026	2.63	0.314	7.96
Other basic organic chemical manufacturing	2.52	3.97	6.48	3.02	7.64	0.14	1.01	0.035	10.7
Motor vehicle parts manufacturing	1.87	9.57	11.4	0.024	0	0.375	11.2	0.364	3.34
Iron and steel mills	1.46	1.21	2.67	11.4	0.198	10.8	77.5	0.004	0.485
Alumina refining and primary aluminum production	1.32	3.89	5.21	0.633	1.64	2.44	3.63	0.021	2.1
Plastics material and resin manufacturing	1.14	2.53	3.67	0.255	1.48	0.021	0.247	0.002	2.1
Light Truck and Utility Vehicle Manufacturing	0.856	7.95	8.81	0.002	0	0.005	0.475	0.057	1.44
Ferrous metal foundaries	0.814	0.961	1.77	0.042	0	3.23	10.3	0.054	0.051
Metal can, box, and other container manufacturing	0.692	1.41	2.11	0	0	0	0.008	0	0.011
Synthetic rubber manufacturing	0.567	1.01	1.58	0.08	0.251	0	0.079	0	0.023

Top 10 sectors only presented here

Total water withdrawals of $1 million automobile manufacturing

Sector	Water Withdrawals kGal
Total for all sectors	8900
Power generation and supply	5120
Paint and coating manufacturing	868
Cotton farming	775
Grain farming	745
Iron and steel mills	157
Paperboard Mills	126
Cattle ranching and farming	115
Gold, silver, and other metal ore mining	105
Motor vehicle parts manufacturing	80.8
Other basic organic chemical manufacturing	78.2

Top 10 sectors only presented here

Total movement of inputs/freight of $1 million automobile manufacturing via various modes

Sector	Air	Oil Pipe	Gas Pipe	Rail	Truck	Water	Intl Air	Intl Water	Total
	ton-km	ton-km	ton-km	ton-km	ton-km	ton-km	ton-km	ton-km	ton-km
Total for all sectors	5260	53600	45300	1220000	663000	96600	8230	1600000	3690000
Leather and hide tanning and finishing	2730	0	0	45.1	5530	0	738	935	9980
Automobile Manufacturing	562	0	0	829000	231000	445	359	249000	1310000
Motor vehicle parts manufacturing	467	0	0	103000	108000	28.6	2740	111000	325000
Other leather and allied product manufacturing	280	0	0	8.39	352	0	107	3260	4010
Other basic organic chemical manufacturing	123	0	0	9720	3060	2470	40.8	21000	36400
Iron and steel mills	66.8	0	0	41300	51600	11100	48.4	201000	305000
Paint and coating manufacturing	57.5	0	0	1760	4940	29.5	7.25	242	7040
Semiconductor and related device manufacturing	48.8	0	0	150	629	0	171	68.9	1070

Total land use from all sectors from $1 million automobile manufacturing

Sector	Land Use 1000 x ha (kha)
Total for all sectors	0.065
Cattle ranching and farming	0.021
Logging	0.014
Automobile Manufacturing	0.01
Forest nurseries, forest products, and timber tracts	0.01
All other crop farming	0.002
Grain farming	0.001
Light Truck and Utility Vehicle Manufacturing	0.001
Cotton farming	0.001
Truck transportation	0
Oilseed farming	0

TRACI impacts from all sectors from $1 million automobile manufacturing

Sector	Glob Warm	Acidif Air	HH Crit Air	Eutro Air	Eutro Water	OzoneDep	Smog Air	EcoTox (low)	HH Cancer (low)	HH NonCancer (low)	EcoTox (high)	HH Cancer (high)	HH NonCancer (high)
	kg CO2e	kg SO2e	kg PM10e	kg Ne	kg Ne	kg CFC-11e	kg O3e	kg 2,4D	kg benzene eq	kg toluene eq	kg 2,4D	kg benzene eq	kg toluene eq
Total for all sectors	569000	2880	892	79	0.305	0.562	39200	50.9	106	76200	52.9	707	1090000
Power generation and supply	180000	1030	205	15.1	0.003	0	8310	2.09	3.06	1720	2.1	9.16	9060
Iron and steel mills	108000	127	46.5	3.75	0.058	0	2090	1.41	11.3	12500	1.66	12.4	13300
Truck transportation	24100	172	73.8	9.42	0	0	5330	0	0	0	0	0	0
Oil and gas extraction	20400	32.3	1.97	1.67	0	0	1130	0	0	0	0	0	0
Cattle ranching and farming	12400	81.8	15	5.08	0	0	62.4	0	0	0	0	0	0
Other basic organic chemical manufacturing	12100	44.6	9.21	1.26	0.044	0.088	715	0.058	1.02	127	0.199	4.72	312
Motor vehicle parts manufacturing	11600	44.2	14	1.54	0	0.026	968	4.45	2.14	1680	4.59	7.44	16300
Petroleum refineries	11200	26.7	5.58	0.493	0.009	0.001	282	0.028	0.309	74.2	0.038	0.84	89.1
Automobile Manufacturing	10800	38	11.4	1.23	0	0	1490	0.202	0.53	75.9	0.207	6.37	161
Alumina refining and primary aluminum production	10700	105	28.8	0.629	0.013	0.12	341	0.137	0.934	311	0.151	19.6	11900

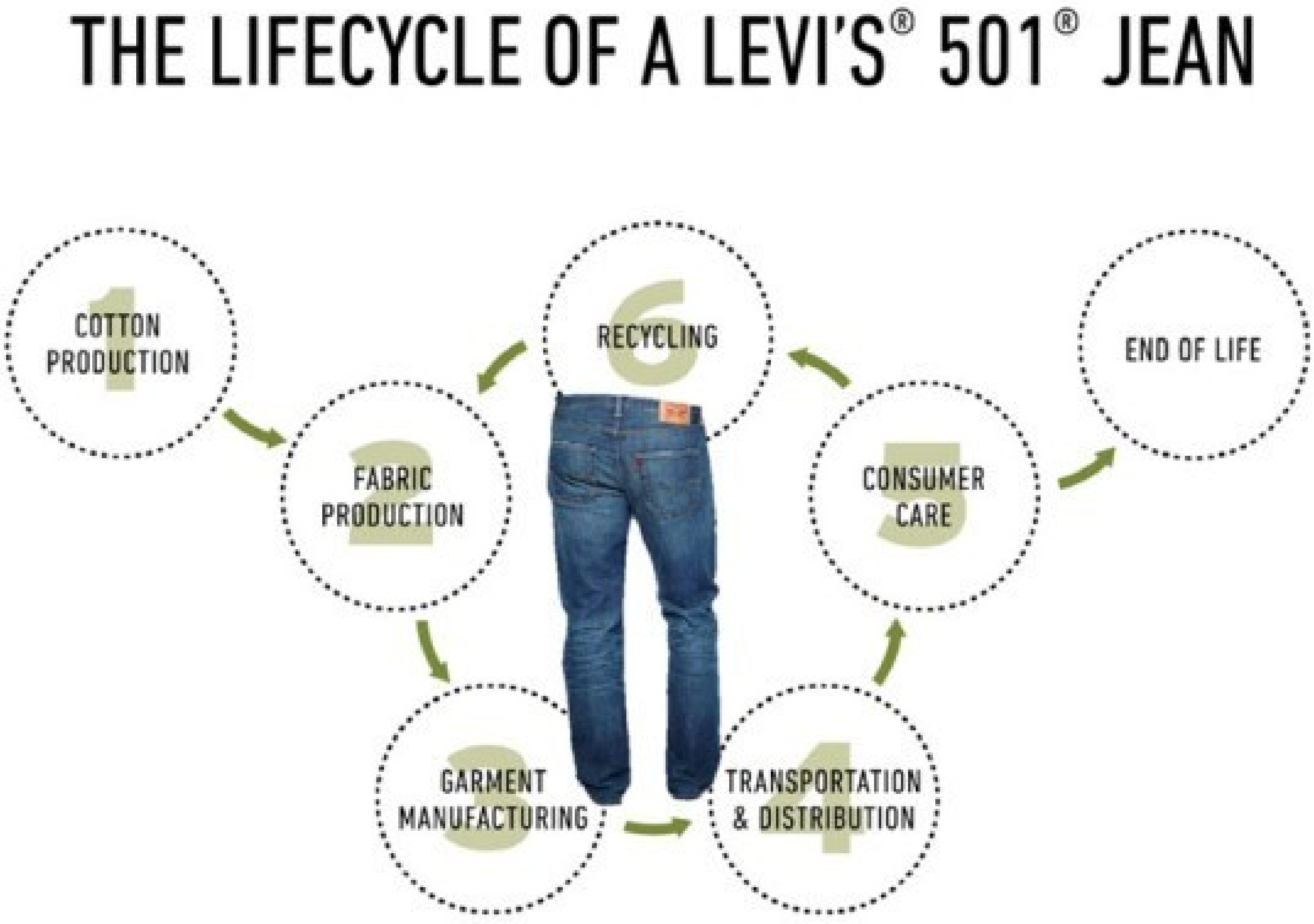
NESPRESSO

Life-Cycle Assessment of a cup of ***Nespresso*** *Expressed in % CO_2eq per cup (Quantis, LCA 2013)*

https://www.nestle-nespresso.com/newsandfeatures/Life-Cycle-Analysis-Reducing-our-footprint

The Life Cycle of a Jean

http://store.levi.com/waterless/



Tshirt

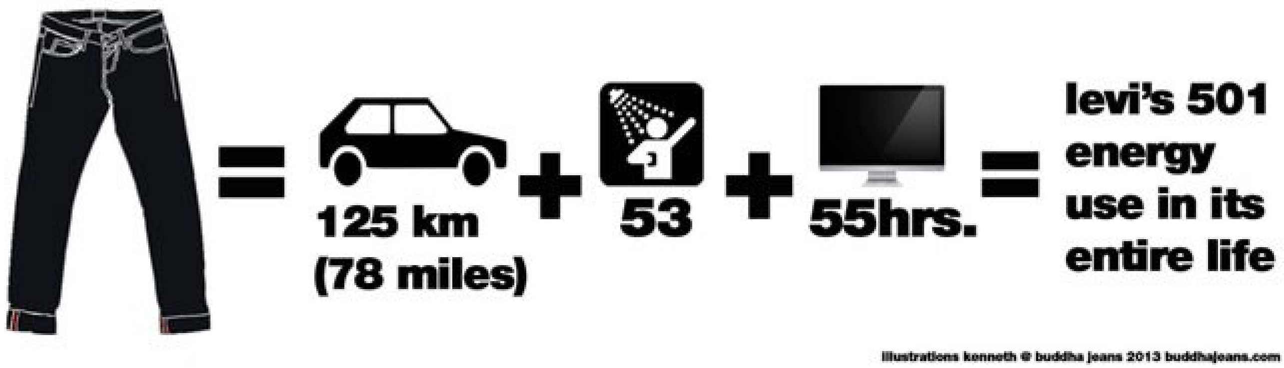
https://www.youtube.com/watch?v=5Ckgw5xvZV4
4 min

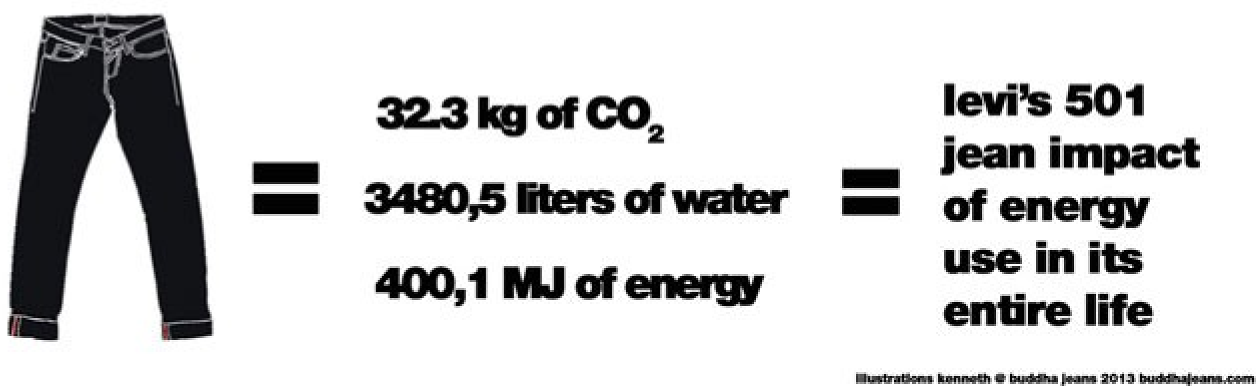
Good Guide

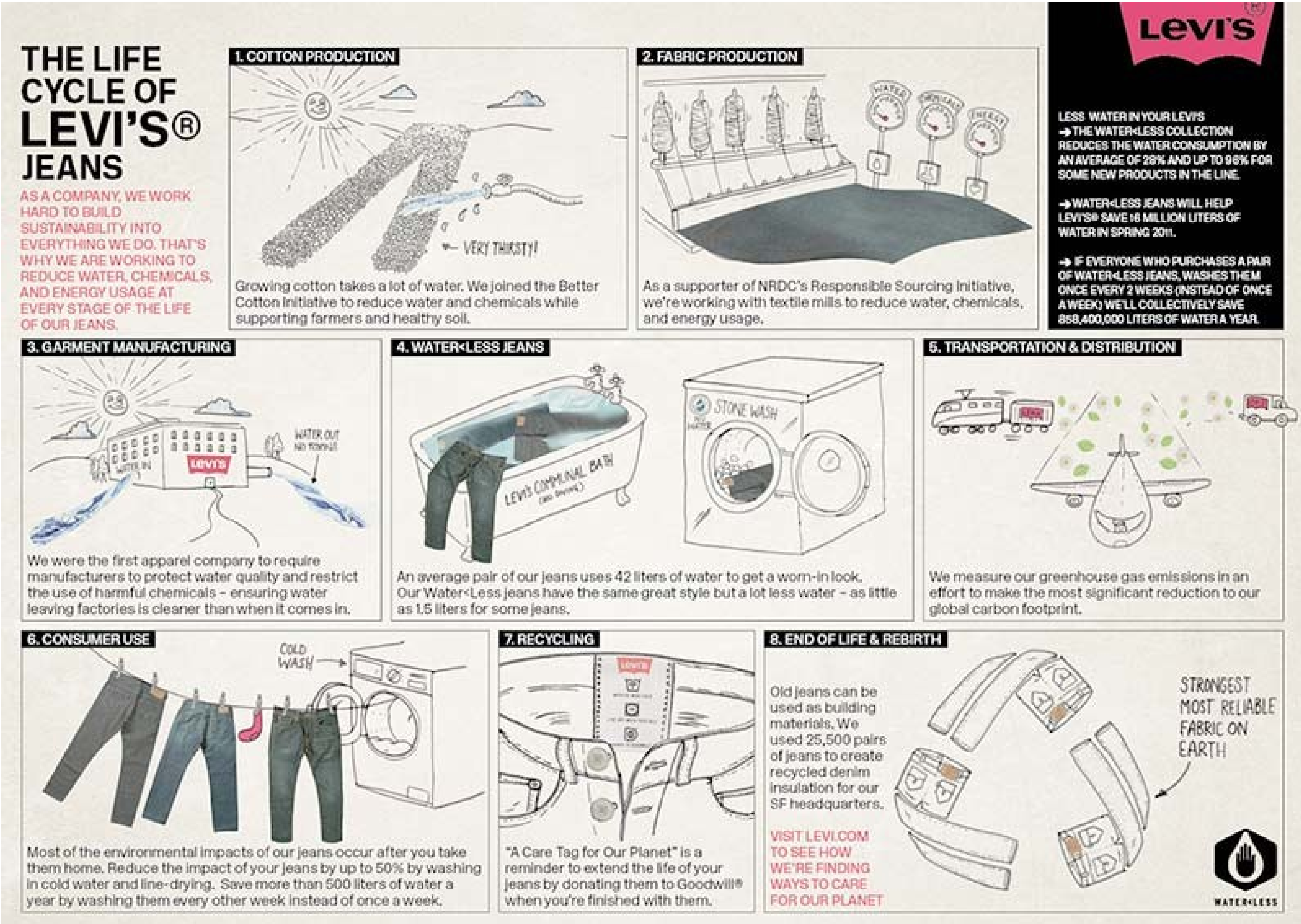
https://www.youtube.com/watch?v=TVBxlMx6nK4
10 min

http://levistrauss.com/wp-content/uploads/2015/03/Fact-Sheet-for-LCA-FINAL.pdf

Product life cycle Assessment (LCA) study: [Levi Strauss Co]

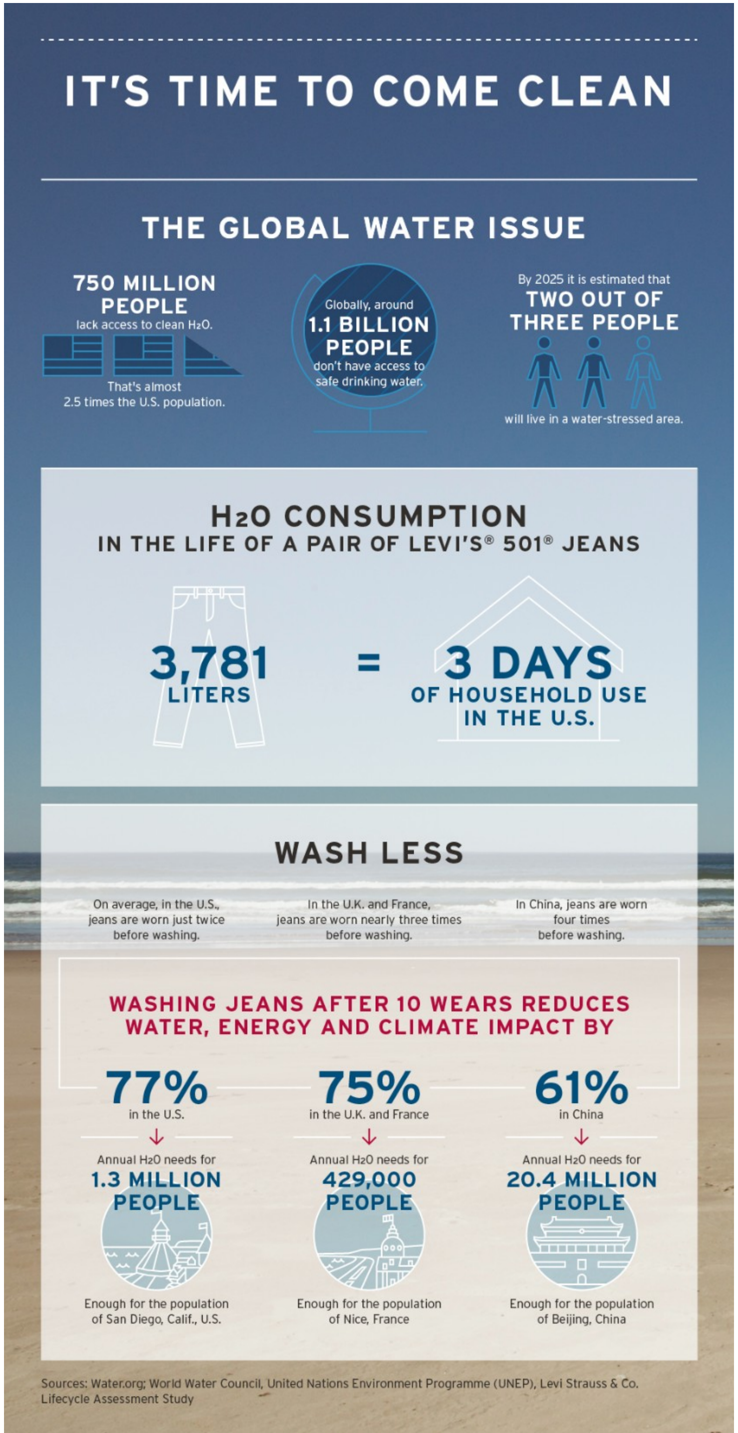





THE LIFE CYCLE OF LEVI'S® JEANS
AS A COMPANY, WE WORK HARD TO BUILD SUSTAINABILITY INTO EVERYTHING WE DO. THAT'S WHY WE ARE WORKING TO REDUCE WATER, CHEMICALS, AND ENERGY USAGE AT EVERY STAGE OF THE LIFE OF OUR JEANS.
1. COTTON PRODUCTION
VERY THIRSTY!
Growing cotton takes a lot of water. We joined the Better Cotton Initiative to reduce water and chemicals while supporting farmers and healthy soil.
2. FABRIC PRODUCTION
WATER
ENERGY
As a supporter of NRDC's Responsible Sourcing Initiative, we're working with textile mills to reduce water, chemicals, and energy usage.
LEVI'S
LESS WATER IN YOUR LEVI'S
→ THE WATER<LESS COLLECTION REDUCES THE WATER CONSUMPTION BY AN AVERAGE OF 28% AND UP TO 96% FOR SOME NEW PRODUCTS IN THE LINE.
→ WATER<LESS JEANS WILL HELP LEVI'S® SAVE 16 MILLION LITERS OF WATER IN SPRING 2011.
→ IF EVERYONE WHO PURCHASES A PAIR OF WATER<LESS JEANS, WASHES THEM ONCE EVERY 2 WEEKS (INSTEAD OF ONCE A WEEK) WE'LL COLLECTIVELY SAVE 858,400,000 LITERS OF WATER A YEAR.
3. GARMENT MANUFACTURING
WATER IN
WATER OUT
LEVI'S
We were the first apparel company to require manufacturers to protect water quality and restrict the use of harmful chemicals – ensuring water leaving factories is cleaner than when it comes in.
4. WATER<LESS JEANS
LEVI'S COMMUNAL BATH
STONE WASH
An average pair of our jeans uses 42 liters of water to get a worn-in look. Our Water<Less jeans have the same great style but a lot less water – as little as 1.5 liters for some jeans.
5. TRANSPORTATION & DISTRIBUTION
We measure our greenhouse gas emissions in an effort to make the most significant reduction to our global carbon footprint.
6. CONSUMER USE
COLD WASH
Most of the environmental impacts of our jeans occur after you take them home. Reduce the impact of your jeans by up to 50% by washing in cold water and line-drying. Save more than 500 liters of water a year by washing them every other week instead of once a week.
7. RECYCLING
"A Care Tag for Our Planet" is a reminder to extend the life of your jeans by donating them to Goodwill® when you're finished with them.
8. END OF LIFE & REBIRTH
Old jeans can be used as building materials. We used 25,500 pairs of jeans to create recycled denim insulation for our SF headquarters.
VISIT LEVI.COM TO SEE HOW WE'RE FINDING WAYS TO CARE FOR OUR PLANET
STRONGEST MOST RELIABLE FABRIC ON EARTH
WATER<LESS

cussion Levi & Patagonia

https://www.youtube.com/watch?v=YSLpONKlECs



Circularit


Lifecycle of a Starbucks Breakfast Blend K-Cup
Raw Materials
The primary raw materials used as the basis for the fabrication of the K-Cup are corn, crude oil, and natural gases for making plastic, wood for making coffee filters, Bauxite Ore for making Aluminum, and coffee beans for producing coffee grounds. These materials were acquired either through the use of farming or excavation. Both methods utilize human labor, energy from fossil fuels, chemical energy, and heavy use of mechanical construction and farming equipment. The use of other raw materials like water, sunlight, and resources for making fertilizers, pesticides, and solutions to decompose Earth for excavation, are integral in the overall manufacture of the product.
Energy Embodied
Many different types of energies are used throughout the life cycle of the K-Cup. Raw materials are converted to secondary materials through the use of intentional chemical reactions, often times these chemical reactions are prompted by the use of mechanical or thermal energy. The raw materials are converted into usable primary materials, which are then converted into secondary materials, which are then reformed and assembled to create a final product. Various melting, bonding, purification, and assembling processes involve the use of specialized machines and heating elements. Many of these operations are energized by electricity, in addition human labor is another notable source of energy.
Final Product
The K-Cup is a self contained brewing system designed specifically for Keurig Brewers. The small cup has four main components, the smooth plastic shell, the crêped paper coffee filter, the Starbucks Breakfast Blend coffee grounds located in the coffee filter, and finally the aluminum lid that seals the cylindrical container. The K-Cup is used once to brew a single serving of coffee and then the cup may be disposed of.
Waste and Emissions
Only two elements of the K-Cup are recyclable, the aluminum lid and the coffee filter. The lid can be recycled with aluminum products and the filter can be recycled with paper products. The plastic shell, the most significant component of the K-Cup structure, cannot be recycled. There is some controversy over the pros and cons of this K-Cup technology because so much of the product does ultimately end up in a landfill upon disposal. Other production processes throughout the life cycle also create waste, for example Bauxite conversion to Aluminum releases red mud through the filtration process of solid and metallic oxide-bearing impurities. Runoff sediment is one of the largest, and often over-looked, cases of water waste and cannot be re-used because of water contamination from pesticides.
A More Sustainable Solution
The K-Cup requires the use of a lot of non-renewable resources. Green Mountain Coffee Growers, the owner of the K-Cup patent, is in the process of manufacturing a K-Cup that is more environmentally friendly while still giving you the full benefits of K-Cup brewing. They seek to achieve this goal by manufacturing a K-Cup where the plastic is made entirely out of PLA. PLA is a plastic produced from corn which makes it recyclable. The plastic in the K-Cup is currently 19% PLA. If a K-Cup can be created that is 100% PLA plastic then it will transform the product into a guilt free way to get your morning brew.
BREAKFAST BLEND
MEDIUM
Design 40A
Winter 2014
Starbucks Breakfast Blend
K-Cup
Thea Kaiser
Adam Rosado
Betty Zhou